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Bunch Compressors and Turn Around Loop for the CLIC Main Beam

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Abstract

To achieve the short bunch length needed for the CLIC main beam, the long bunches coming out of the damping ring have to be compressed longitudinally in two bunch compressor chicanes without spoiling their emittances. Suitable chicane layouts are presented which were found in computer simulations including coherent synchrotron radiation effects. Additionally, a possible layout of the turn around loop directing the beam into the main linac is shown. It was optimized taking into account the effects of incoherent and coherent synchrotron radiation. This paper contains transparencies presented at the CLIC Workshop held at CERN in October 2007.

Acknowledgements

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Bunch Compressors and Turn Around Loop for the CLIC Main Beam

-> Parameter Overview

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-> Summary / Outlook

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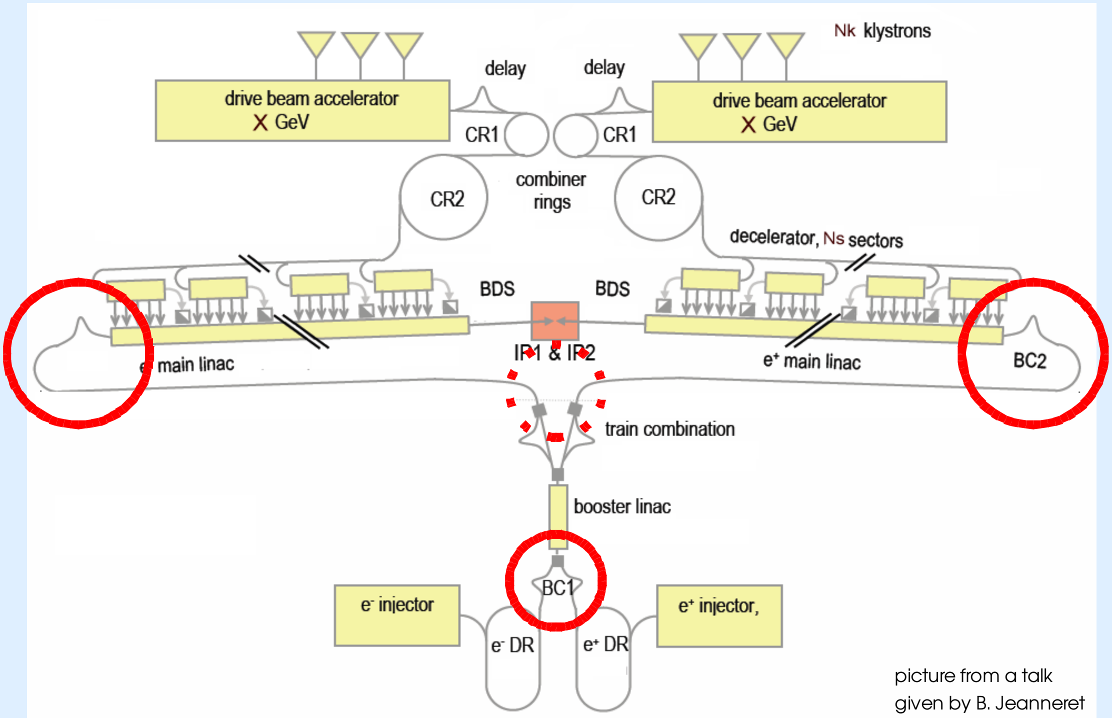
My Tasks for the CLIC Main Beam



picture from a talk given by B. Jeanneret

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Old (30 GHz) vs. New (12 GHz) Main Beam Parameters

Specification in front of BC1:

	Old	New
E_0	= 2.424 GeV	
Q_0	= 0.41 nC	0.67 nC
σ_s	= 1500 μm	
I_{peak}	= 33 A	53 A
$\epsilon_{n,x}$	= 550 nm rad	430 nm rad
$\epsilon_{n,y}$	= 3 nm rad	4 nm rad
$\frac{\sigma_{E,unc}}{E_0}$	= 0.13 %	0.137 %
$\frac{1}{E_0}\frac{dE}{ds}$	$= -5.2\ \mathrm{m}^{-1}$	$-7.8\ \mathrm{m}^{-1}$

BC1

$R_{56} = -19.2$ cm

$R_{56} = -12.7$ cm

behind BC1:

	Old	New
σ_s	= 250 μm	175 μm
I_{peak}	= 200 A	460 A
$\epsilon_{n,x}$	< 570 nm rad	450 nm rad
$\epsilon_{n,y}$	< 4 nm rad	4 nm rad
$\frac{\sigma_{E,tot}}{E_0}$	= 0.8 %	1.17 %

in front of BC2:

	Old	New
E_0	= 9 GeV	
Q_0	= 0.41 nC	0.67 nC
σ_s	= 250 μm	175 μm
I_{peak}	= 200 A	460 A
$\epsilon_{n,x}$	< 570 nm rad	
$\epsilon_{n,y}$	< 4 nm rad	
$\frac{\sigma_{E,unc}}{E_0}$	= 0.2 %	0.32 %
$\frac{1}{E_0}\frac{dE}{ds}$	$= -70.5\ \mathrm{m}^{-1}$	$-69.6\ \mathrm{m}^{-1}$

BC2

$R_{56} = -1.4$ cm

$R_{56} = -1.35$ cm

Specification behind BC2:

	Old	New
σ_s	= 30 μm	44 μm
I_{peak}	= 1670 A	1820 A
$\epsilon_{n,x}$	< 600 nm rad	
$\epsilon_{n,y}$	< 5 nm rad	10 nm rad
$\frac{\sigma_{E,tot}}{E_0}$	= 1.8 %	1.26 %

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Design Considerations / Constraints

Bunch Compressors BC1 and BC2:

-> perform full compression in both chicanes (i.e. get upright ellipses), then in both chicanes the required R_{56} and the energy chirp depend only on the bunch length behind BC1

-> several effects influence the choice of this bunch length:
- wake fields in the booster linac and the transport line
- chromaticity and CSR in the turn around loop
- CSR in BC1 and BC2

-> full optimization of BC2 was performed for old CLIC parameters, BC1 was partially optimized

-> decided not to change the chicane layouts too much for the new parameters

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Design Considerations / Constraints

Important boundary condition:

-> full compression in BC1 requested, but not mandatory

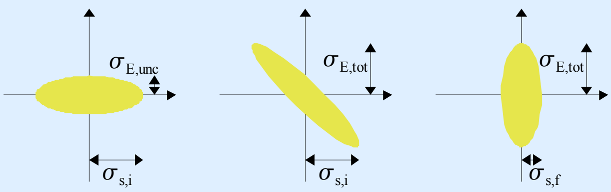
-> definitely full compression in BC2 needed

As long as full compression is requested in both BCs:

-> the R_{56} values and the energy chirps are coupled between both chicanes

-> R_{56} of BC2 can only be reduced by compressing stronger in BC1, not by increasing energy chirp!

-> stronger compression in BC1 only by using higher energy chirp and lower R_{56}



$$\sigma_{\mathrm{s,f}}=\sqrt{\left(1-\frac{1}{E_0}\frac{dE}{ds}R_{56}\right)\sigma_{s,i}^2+R_{56}^2\left(\frac{\sigma_{\mathrm{E,unc}}}{E_0}\right)^2}$$

$$\sigma_{\mathrm{E,tot}}=\sqrt{\sigma_{\mathrm{E,unc}}^2+\sigma_{\mathrm{s,i}}^2\left(\frac{1}{E_0}\frac{dE}{ds}\right)^2}$$

$\epsilon_{\mathrm{long}}=\sigma_{\mathrm{s,f}}\sigma_{\mathrm{E,tot}}$ only for full compression !!!

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Design Considerations / Constraints

Turn Around Loop:

-> based on CLIC CDR (CERN 2000-008), chapter 2.2.5 and CLIC Note 292

-> main complication: high beam energy and consequently strong ISR emittance growth

-> CSR and chromaticity can be controlled by good layout

-> minimize bending of the beam, a turn around loop loop just needs a 180 deg arc and a dog leg to correct transverse offset (i.e. first bending 90 deg in one direction and then 270 deg in the other is unnecessary)

-> loop should be as short as possible

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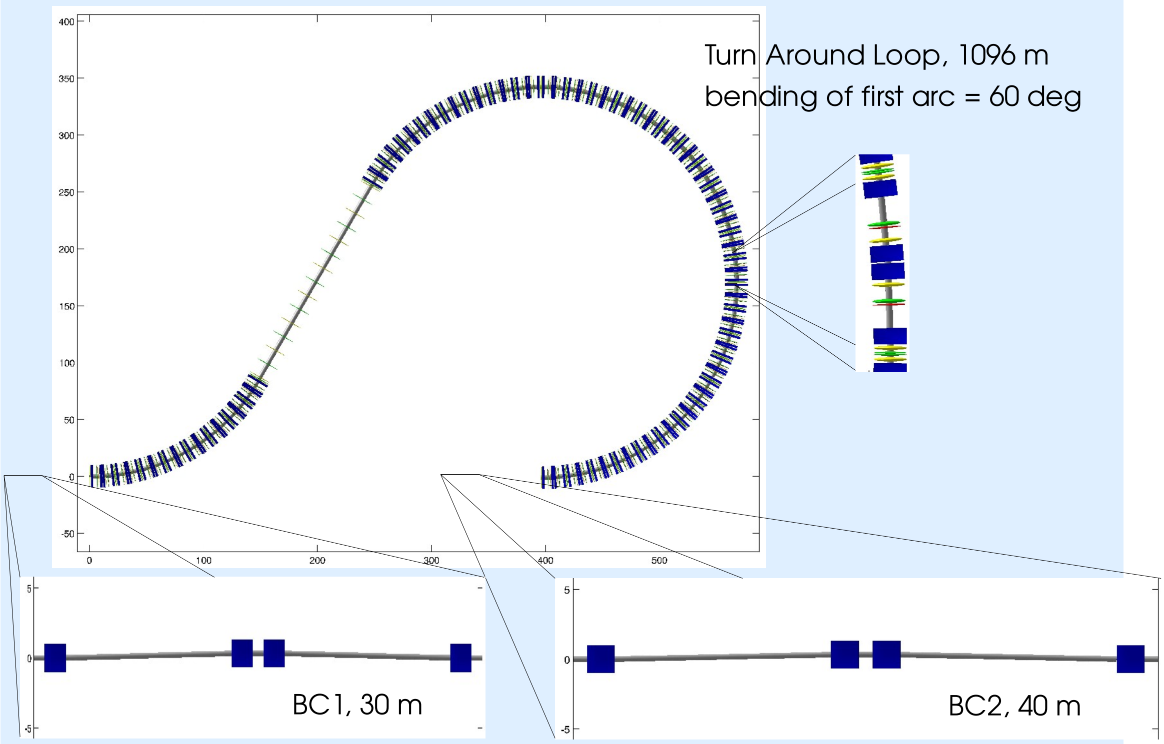
Beam Line Overview



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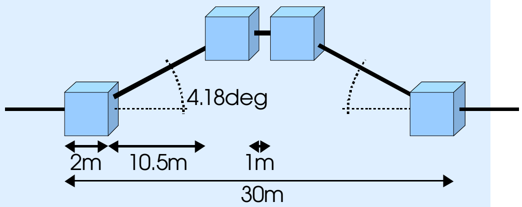
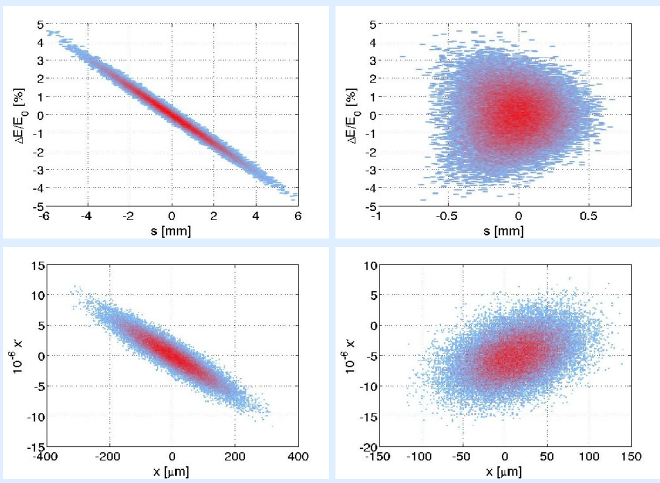
BC1 Simulation Results, 1D CSR

$$E_0 = 2.4\ \text{GeV}$$
$$Q_0 = 0.67\ \text{nC}$$
$$\sigma_s = 1500\ \mu\text{m}$$
$$I_{peak} = 53\ \text{A}$$
$$\epsilon_{n,x} = 400\ \text{nm rad}$$
$$\epsilon_{n,y} = 4\ \text{nm rad}$$
$$\frac{\sigma_{E,unc}}{E_0} = 0.14\ \%$$
$$\frac{1}{E_0}\frac{dE}{ds} = -7.8\ \text{m}^{-1}$$



longitudinal phase space

transverse phase space



initial final

$$\sigma_s = 178\ \mu\text{m}$$
$$I_{peak} = 450\ \text{A}$$
$$\epsilon_{n,x} = 440\ \text{nm rad}$$
$$\epsilon_{n,y} = 4\ \text{nm rad}$$
$$\frac{\sigma_{E,tot}}{E_0} = 1.2\ \%$$

405 nm rad
with shielding

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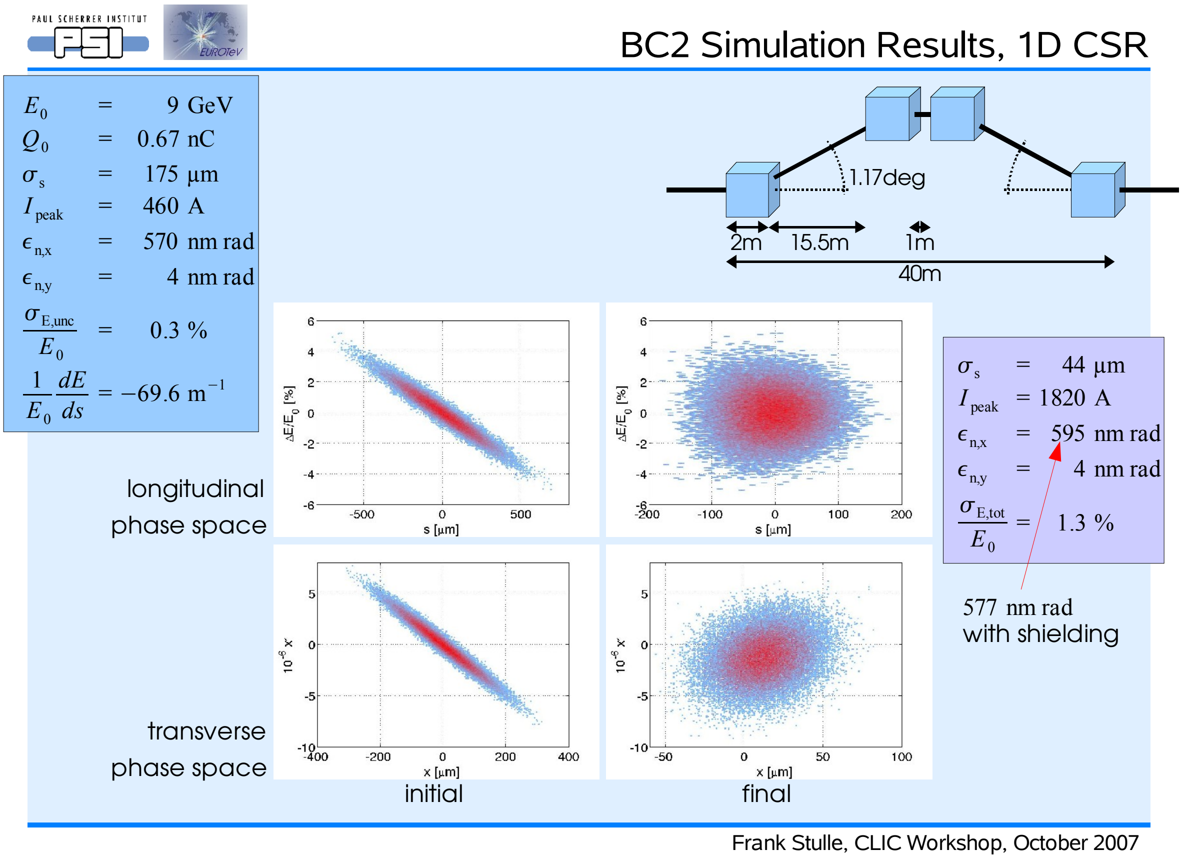

BC2 Simulation Results, 1D CSR
E_0 = 9 GeV
Q_0 = 0.67 nC
σ_s = 175 µm
I_{peak} = 460 A
$\epsilon_{n,x}$ = 570 nm rad
$\epsilon_{n,y}$ = 4 nm rad
$\frac{\sigma_{E,unc}}{E_0}$ = 0.3 %
$\frac{1}{E_0}\frac{dE}{ds} = -69.6\ m^{-1}$
1.17deg
2m
15.5m
1m
40m
longitudinal phase space
transverse phase space
initial
final
σ_s = 44 µm
I_{peak} = 1820 A
$\epsilon_{n,x}$ = 595 nm rad
$\epsilon_{n,y}$ = 4 nm rad
$\frac{\sigma_{E,tot}}{E_0}$ = 1.3 %
577 nm rad with shielding
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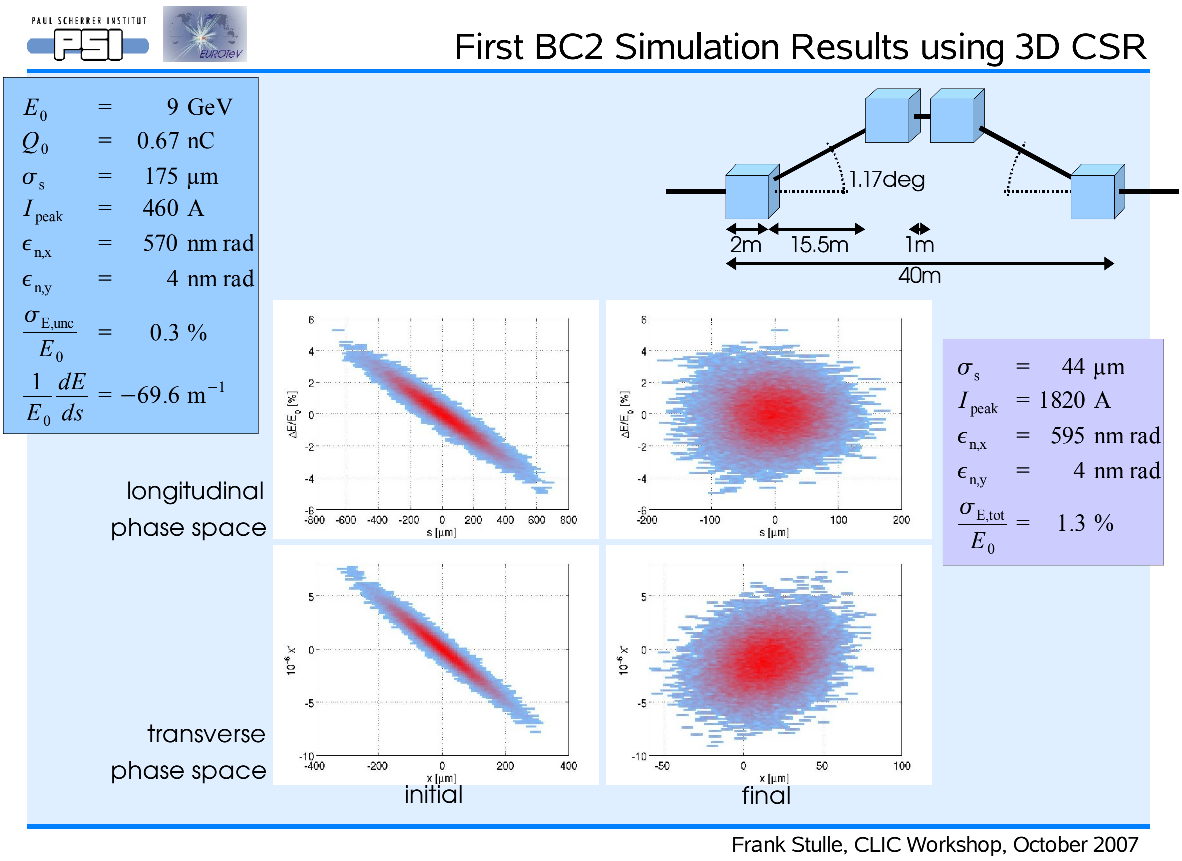

First BC2 Simulation Results using 3D CSR
E_0 = 9 GeV
Q_0 = 0.67 nC
σ_s = 175 µm
I_{peak} = 460 A
$\epsilon_{n,x}$ = 570 nm rad
$\epsilon_{n,y}$ = 4 nm rad
$\frac{\sigma_{E,unc}}{E_0}$ = 0.3 %
$\frac{1}{E_0}\frac{dE}{ds} = -69.6\ m^{-1}$
1.17deg
2m
15.5m
1m
40m
longitudinal phase space
transverse phase space
initial
final
σ_s = 44 µm
I_{peak} = 1820 A
$\epsilon_{n,x}$ = 595 nm rad
$\epsilon_{n,y}$ = 4 nm rad
$\frac{\sigma_{E,tot}}{E_0}$ = 1.3 %
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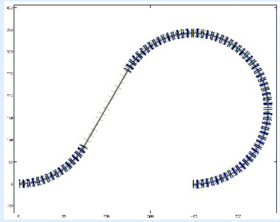
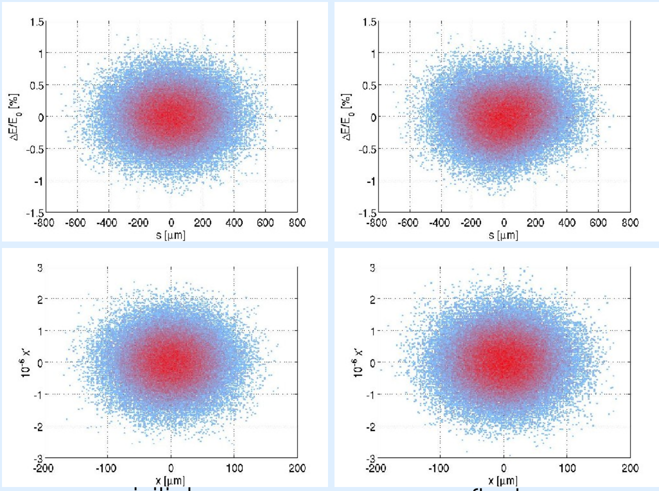
Turn Around Loop Simulation Results, 1D CSR

$$E_0 = 9\ \text{GeV}$$
$$Q_0 = 0.67\ \text{nC}$$
$$\sigma_s = 175\ \mu\text{m}$$
$$I_{peak} = 460\ \text{A}$$
$$\epsilon_{n,x} = 500\ \text{nm rad}$$
$$\epsilon_{n,y} = 4\ \text{nm rad}$$
$$\frac{\sigma_{E,unc}}{E_0} = 0.32\ \%$$
$$\frac{1}{E_0}\frac{dE}{ds} = 0.0\ \text{m}^{-1}$$



longitudinal phase space

transverse phase space



initial final

$$\sigma_s = 175\ \mu\text{m}$$
$$I_{peak} = 460\ \text{A}$$
$$\epsilon_{n,x} = 560\ \text{nm rad}$$
$$\epsilon_{n,y} = 4\ \text{nm rad}$$
$$\frac{\sigma_{E,tot}}{E_0} = 0.32\ \%$$

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Summary / Outlook

-> Required parameter set for 12 GHz frequency complete

-> Chicane and electron beam parameters adjusted to match new specifications

-> Created layout of Turn Around Loop

-> Performed simulations of chicanes and the loop including ISR and CSR

-> CSR in chicanes is important as long as no shielding effects due to the vacuum chamber are considered, in the loop CSR has no major impact

-> Chromaticity of the loop is o.k., as long as energy spread is not too high

-> Main source of emittance growth in the loop is ISR

-> First 3D CSR simulations of BC2 are very promising

-> Continue 3D CSR simulations for BC2 and start with BC1, 3D CSR (using CSRTrack or TraFiC4) in loop seems unrealistic for the moment, option could be CSR model developed by R. Talman

-> Try to get more realistic initial charge distributions

-> For the moment no layout changes are planned, unless someone requests changes or by chance I find some optimizations

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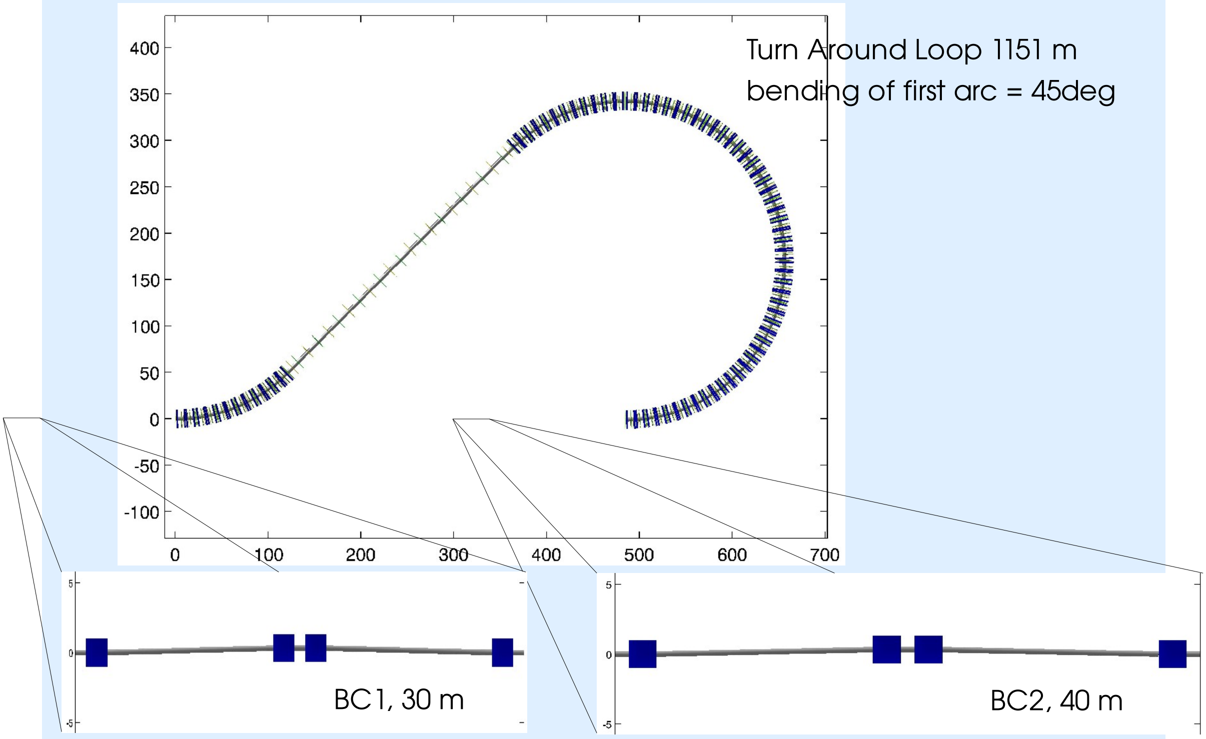
Alternative Beam Line Overview



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